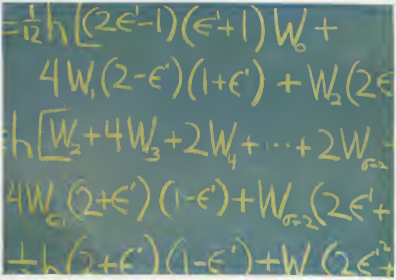
MECHELECIV

THE STUDENTS MAGAZINE • VOLUME 27 • DECEMBER 1968 • NUMBER 3

THE GEORGE WASHINGTON UNIVERSITY

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

Westinghouse needs engineers with oceans of knowledge



or knowledge of oceans.

Our Deepstar manned submersible can explore down to 4,000 ft. We're designing one to go 20,000. Our scanning sonar makes "sound" images of the ocean floor and anything on it. Our Oceanographic Laboratory on Chesapeake Bay is the world's largest.

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You can be sure...if it's **Westinghouse**

the Mecheleciv

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Christmas cheer has a way of hampering everybody's study habits. Mr. & S. Claus contributed by the Hecht Company, Tyson's corner branch. Photo by J. R. Black.

FRONTISPIECE

Santa's sleigh for 1968 — twelve inches of steam power replaces his long outdated reindeer. Contributed by James F. Bladen. Photo by J.R. Black.

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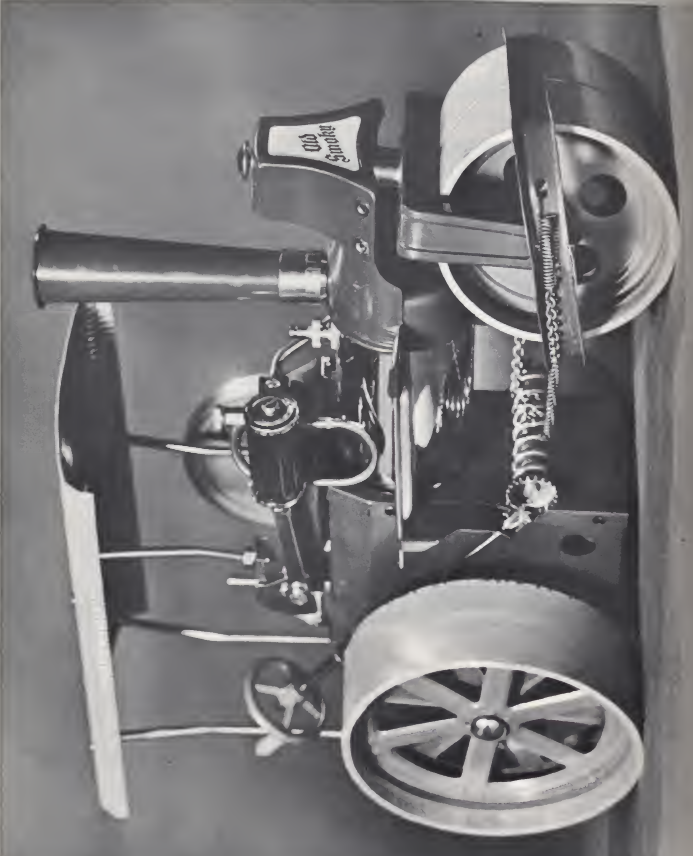

Old Smoky

MECHELECIV

On November 6, 1968 the Executive Committee of the George Washington University Student Council voted to post collateral for some George Washington University students who participated in an Election Day demonstration. The protest march began near the Lincoln Memorial, proceeded to Lafayette Park across the street from the White House, and ended in front of James Monroe Hall on the George Washington Campus. Acts leading up to the arrests of the demonstrators were encouraged by a campus organization called the Students for a Democratic Society (SDS). This minority group, acting as individuals and not as representatives of the University, indulged itself by ignoring the avenues of communication that the University and students have previously established. In an ensuing melée, several persons were arrested and booked on charges ranging from jaywalking to disorderly conduct.

Faced with this situation, which warranted no action at all, the members of the Executive Committee stumbled into action. According to a member of the committee, the posting of the collateral was brought on solely because of "humanitarian reasons". The "Mecheleciv" will ignore this remark except for the reflection that, as far as our staff could ascertain, no one has ever expired from an overnight stay in the D.C. jail. If it were not for "humanitarian" reasons, then why did the committee post bail? The "Mecheleciv" is at a loss to explain unless members of this Committee had a hidden purpose in supporting a minority position over the sentiments of the vast majority, thereby not upholding the interests of the GWU student body as a whole. In this situation, it appears that the Committee took hasty action to lend credence to an independent protest.

At this point, it would be to the benefit of everyone concerned if the Executive Committee submitted this problem to student referendum so that if this situation should reappear in the future, the Executive Committee will act in a representative manner.

LETTER TO THE EDITOR

One part of the "Engineers' Creed" (as adopted by the National Society of Professional Engineers) states, "I pledge to participate in none but highest enterprise; to live and work according to . . . the highest standards of professional conduct; to place the honor and standing of the profession before personal advantage." The School of Engineering and Applied Science of the George Washington University is a professional School. Yet some students of the SEAS do engage in cheating. Some students copy from books or companions on tests; some merely copy homework that is to be turned in. But there is no degree of dishonesty. I feel that the best solution to this problem would be an Honor Code. This code should consist of at least five parts:

1) An Honor Court of three or five members should be appointed (by the Dean, faculty, or Engineers' Council) for the purpose of judging any persons accused of breaking the Code.

2) Any person using any material not specifically allowed by the instructor of the course (books, notes, tests of other people) breaks the Code.

3) Any person knowingly aiding a fellow student to break the Code or witnessing such an act without reporting it is an equally guilty party.

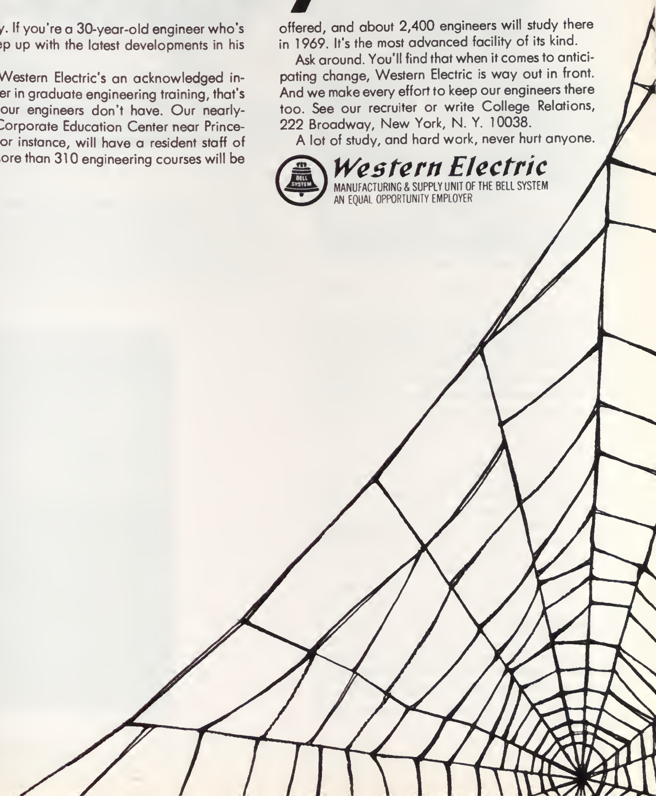
4) Each student should have to sign a copy of the Code at registration prior to each semester.

5) Any person found guilty by the Honor Court will suffer the penalties for academic dishonesty as stated on page 22 of the SEAS 1968-69 Catalogue.

I have heard several criticisms of the Code. One is that the purpose of the School is to teach and not to act as a moral guardian. However, as long as the School gives grades, it should try to make these grades as true and honest as possible. (I do not argue the value of grades; now, and probably for some time to come, we do have a grading system.) Another criticism I have heard is that some instructors consider student to student cooperation an important part of the learning process. This case is adequately covered in part 2 of the Code.

I urge the Dean, faculty, and student body of the SEAS to consider an Honor System to help build a great School. The system could serve as an example to the entire University. I plan to propose an Honor System to the Engineers' Council at its next meeting.

Myron A. Schloss



Campus News

GW ADOPTS NEW ACADEMIC CALENDAR

A new academic calendar, which includes a three week reading-exam period, will go into effect during the 1969-70 academic year at George Washington and will be given a trial run of three years. At present, the examination period is only one week, with some exams beginning two days after the classes.

Dr. Harold F. Bright, vice-president for academic affairs, explained that the first week of the reading exam period is flexible and may be used for individual study or research projects. Professors may hold regular class meetings during the week if they wish. Examinations will be scheduled only during the last two weeks of the three-week period. The period will begin immediately after the Christmas recess in 1969.

The new system will apply to the Columbian College of Arts and Sciences, The Graduate School of Arts and Sciences, and the Schools of Engineering and Applied Science, Education, Government and Business Administration, Public and International Affairs, the College of General Studies on Campus, and the Division of University Students.

ENGINEERS' WEEK

Myron Schloss has been appointed as the new chairman of Engineers' Week. It will be held the third week in February, and through exhibits will demonstrate opportunities and aspects of engineering to the students and the general public.

DH HOUSE

The new furniture for the Davis-Hodgkins House has all arrived. It includes couches and chairs for the living room and new office furniture for the MECHELECIV. A total of $2000 was spent for this furniture and it is hoped that all engineers will use the new facilities at the DH House.

DH House Interior . . .

ELECTIONS

Results of the election for Freshman Representatives to the Engineers' Council have been tallied. The winners are: Mark H. Litchfield, Michael Rothschild.

RESEARCH CO-OP

George Washington University and the National Bureau of Standards have entered an agreement to cooperate in training and research on the advanced graduate level in the general sciences. Affecting GW's departments of physics, chemistry, and mathematics and the GW School of Engineering and Applied Science, the arrangements provide for an exchange of personal and a maximum use of the facilities of both institutions.

Dr. Carl Walther, assistant vice president for academic affairs, said the University can now use the services of top level personnel from the National Bureau of Standards as adjunct professors. "They can help plan curricula in departmental meetings and can advise and direct the research of graduate students," he added. In addition, The National Bureau of Standards will make available its specialized facilities, which include a radiation physics lab with a 100 million volt linear accelerator, for graduate students or professors from GW.

FLEXIBLE STRAIN SENSORS

Dr. Robert M. Moore, graduate of George Washington, twists an aluminum substrate holding thin-film strain sensors developed at RCA Laboratories, Princeton, N.J. The sensors, 10 times more sensitive to mechanical strain than available piezoresistive semiconductors transducers, can be fabricated on a variety of substrates, including plastic (center foreground) and glass (at the right). See Tech News.

RECRUITMENT

Mr. Charles Brown, the Coordinator of Recruitment and Admissions, will devote himself to the problems of recruitment and admissions for the School of Engineering and Applied Science. He will visit all the high schools and junior colleges in the area to present the SEAS story in an effort to convince these students to come to SEAS for an outstanding and fully accredited engineering education. He will work through the high school science teachers,

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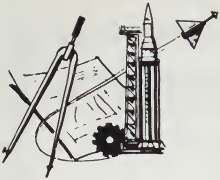


Tech News

Edited by David R. Armstrong, E.E., 70

DEEP OCEAN WORK BOAT

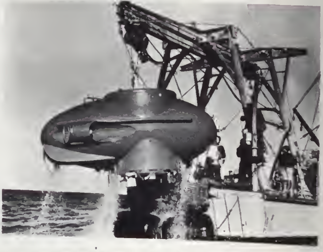
Designed without view ports, the Deep Ocean Work Boat (DOWB) of General Motors AC Electronics-Defense Laboratories provided a new optical viewing capability with 360-degree visibility for its two-man crew, a "first" among submersibles developed to perform useful undersea work.

As the 17-foot-long orange-hued DOWB descended in its final sea test this past summer its pilot and co-pilot became the first in a submersible to observe both their forward movement, the surrounding sea and ocean floor without restrictive or isolated view ports and crew discomfort. This was accomplished by wide-angle "fish-eye" objective domes above and below the hull, sufficient illumination and the use of closed circuit television. Each of the domes provided complete 180-degree viewing capability through a centrally located optical console. This allowed complete viewing capability by the two crew members simultaneously while in a normal seated position.

DOWB's television screen is centered forward of the seats. Controls for panning the television camera, which is mounted on the manipulator at the bow, are adjacent to the crew.

A sonar system with vertical fan and conical beams permits search, terrain avoidance and beacon homing when required. Upward and downward beaming depth sounding devices, underwater telephone, and a free-running sonic beacon allowing the submersible to be tracked continuously by the mother ship hovering above, are provided.

An electro-mechanical manipulator has six degrees of freedom, which can be compared to the movements possible with the human arm from the shoulder to the finger tips. It has a reach of 49 inches. With a pincer at the end of the manipulator DOWB can emplant and retrieve 50-lb objects or perform other delicate operations. An independently tilting flange on the manipulator mounts the TV camera, lights and sonar transducers.



A. C. Electronics—Defense Laboratories' Deep Ocean Work Boat (DOWB) shown here after a deep submergence test, is designed to perform useful work on the world's continental shelves.

DOWB's propulsion is provided by four propellers, two of which for horizontal movement are shroud-mounted with their motors on the outside of the fairing. Mounted in vertical ducts near the bow and stern are propellers and motors providing vertical movement and a hovering capability. Lead acid batteries, sealed and pressure compensated, are mounted external to the pressure hull within the fiberglass fairing in sea water. The DC current from the batteries is converted to AC to gain a weight and reliability advantage.

DOWB, which has an operational design depth of 6,500 feet, was developed by GM's AC Electronic-Defense Research Laboratories to provide support for the laboratories' work in its Santa Cruz Acoustic Research Facility, industry's only deep-ocean acoustic tracking and submarine noise measurement range.

Westinghouse's Uvicon tube literally "sees in the dark." The tube responds to ultraviolet images, amplifies them electronically, stores them and converts them into television-type electrical signals.

WESTINGHOUSE CAMERA TUBE ABOARD OAO TO MAP INVISIBLE STARLIGHT

A foot-long, 12-ounce television camera tube, scheduled for an historic flight into space from Cape Kennedy, Fla. late in November, will give man an entirely new look at his universe. The tube, called a Uvicon, is a key scientific instrument aboard the National Aeronautics and Space Administration's largest and most instrumented unmanned satellite, the Orbiting Astronomical Observatory, OAO-A2.

Developed by Westinghouse Electric Corporation, four of the Uvicon tubes will map the stars and interstellar space in a space experiment—called Project Celescope—conducted for NASA by the Smithsonian Astrophysical Observatory, Cambridge, Mass. The mapping will be done by means of far ultraviolet radiation(uv). These ultraviolet rays, emitted by celestial bodies, never reach the earth's surface because they are absorbed in the atmosphere. Thus, the Uvicons will give pictures of the heavens that have previously been screened from man's earth-bound observations.

Such pictures offer promise for gaining new insight into theories concerning the atmosphere of young, extremely hot stars, including their age and their chemical composition. Such information might lead to new discoveries about the origin and evolution of the universe.

Project Celescope is a pioneering space experiment dating back to the late 1950's, when the Smithsonian proposed it to NASA and began work with Westinghouse on development of the key Uvicon tube. The project will survey some 100,000 uv stars at a rate of up to 700 per day. An ultraviolet map of the entire sky will require about a year to complete.

The Uvicon is an extremely sensitive camera tube. It is a member of a family of devices known as SEC image tubes, so called for secondary electron conduction, the electronic principle used to strengthen the images they receive. SEC tubes designed to respond to visible light are used for low-light-level surveillance in military, industrial and security applications and in astronomy, since they have the inherent ability to literally "see in the dark."

POLLUTION PREVENTER

Two giant rubberized Pillow tanks have been submerged in the sullied waters of the Anacostia River, launching a new approach to water pollution control.

The 100,000-gallon tanks are part of a system designed by Underwater Storage, Inc. of Washington, D.C., for the temporary storage of sewage overflow triggered by heavy rains. Rather than flowing unprocessed into the Anacostia when drainage systems are overworked, the sewage will be diverted through a pumphouse into the tanks. Later, when the water has receded, the overflow will be pumped out of the tanks to a sewage treatment plant four miles away.

One of two 100,000-gallon rubberized Pillow tanks made by Goodyear and designed to hold sewage overflow caused by heavy rains.

CONTINUED ON NEXT PAGE

The one-year pilot project is being conducted by Underwater Storage under a $560,000.00 contract with the Federal Water Pollution Control Administration. Dr. Harold G. Quase, president of Underwater Storage, said his company believes the temporary storage methods using the collapsible, pillow-shaped tanks made by the Goodyear Tire & Rubber Company is the most economical way for cities to prevent sewage overflow contaminating waters.

Overworked drainage systems are a major problem in many American cities, Dr. Quase said, as they are unable to handle both the millions of gallons of water from rainstorms and the unusual volume of sewage. When a storm fills drains to capacity, both water and sewage flow unprocessed into rivers rather than through sewage treatment plants. He said he expects the Anacostia project to demonstrate the feasibility of his temporary storage concept as a logical alternative to the multimillion-dollar expense of building additional storm and sewer lines.

Each of the tanks is attached to a metal cradle anchored to the bed of the Anacostia River, 17 feet below the surface. Hoses connect the tanks to the pumphouse on the nearby shore. Nearly 1,100 yards of rubber-impregnated nylon fabric were used in building the tanks at Goodyear's plant in Rockmart, Ga. Each weighs 3,000 pounds and is 124 feet long and 24 feet wide. The height of each tank is regulated by straps connected to the cradle.

Dr. Quase said use in a water pollution control project marks a new role for the versatile Pillow tanks, developed by Goodyear in 1951.

130-FOOT RADIO TELESCOPE DEDICATED AT CALTECH'S OWENS VALLEY OBSERVATORY

Dedication of the 130-foot radio telescope at California Institute of Technology's Owens Valley Radio Observatory on October 18 completed the first stage of a major expansion program. The proposed system recommended by the National Academy of Sciences consists of an interferometer array composed of seven more of the giant antennas.

The system would make this the world's most powerful and flexible radio observatory for the study of radio sources in and beyond our galaxy. It would be able to detect objects with radio strengths only 1/20 of those presently detected.

The new antenna is being used with twin 90-foot dishes. To overcome the severe limitations in resolving power of individual radio telescopes, two more steerable antennas can be used in an interferometer array. Many of the techniques used in radio telescopes are similar to those used with optical telescopes. Radio waves are caught in a huge aluminum reflector and focused on a radio receiver positioned at the focal point of the reflector.

The basic design of the new 130-foot antenna was done at Caltech. The detail design, manufacture, partial assembly and tests were done by the Westinghouse Marine Division at Sunnyvale, where the gears and drives for turning the dish, and the trucks and motors to move it along rails on wheels, were also built.

The reflector surface, mounted on a supporting structure of 2400 welded tubes, consists of 852 panels of aluminum surface. The tower assembly, pedestal and base were fabricated from welded large plate and structural steel. The complete mount consists of the counterweighted dish supported by an alidade mounting, pedestal, base and four rail-mounted base trucks. The entire mobile assembly weighs 941,000 pounds.

This 130-foot dish antenna, the first in a proposed array of eight radio telescopes, was recently dedicated at California Institute of Technology's Owens Valley Radio Observatory.

Now that the new telescope has been completed and aligned, it will provide radio astronomers with a much more sensitive tool for detecting and measuring minute celestial signals than they have had previously, Astronomers hope to

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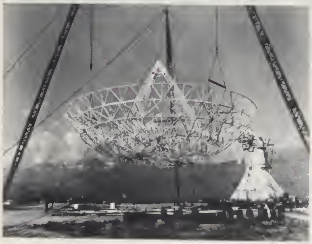


The 130-foot-diameter antenna is shown being lifted to its pedestal at right in a complex hoisting operation conducted by Westinghouse.

obtain many answers to questions that have arisen from previous observations with less sensitive telescopes—and will undoubtedly come up with new questions in the process.

HIGHLY SENSITIVE THIN-FILM STRAIN SENSORS DEVELOPED BY RCA SCIENTISTS

Thin-film diodes 10 times more sensitive to mechanical strain than available piezoresistive semiconductor transducers and 200 times more sensitive than metal wire strain gauges have been developed by RCA scientists, at RCA Laboratories.

The sensors can be fabricated by a relatively simple and inexpensive vacuum evaporation technique. They have low electrical impedances and are compatible with bipolar transistor circuits. Furthermore, the new thin-film transducers eliminated the need for elaborate and delicately positioned mechanical impedance matching structures required by "piezojunction" transducers in applications requiring high sensitivity.

These features indicate the new RCA devices have the potential for a number of applications as pressure transducers and can even be used as switches. In addition, it appears that the thin-film transducers may be used in conjunction with ultrasonic delay lines, such as those employed for buffer memories.

The thin-filmed transducers were developed by Dr. Robert M. Moore and Mr. Charles J. Busanovich under the direction of Dr. Donald S. McCoy, who is in charge of signal processing research at RCA Laboratories. Dr. Moore described the device as an evaporated thin-filmed heterojunction diode that can be evaporated on a variety of substrates ranging in rigidity from very flexible to aluminum to glass.

The electrical characteristics of the strain sensors are established by the geometry of the evaporated thin films while their mechanical characteristics depend upon those of the substrates upon which they are evaporated. This permits the separate adjustment of the electrical and mechanical properties so that optimum performance can be attained.

In a typical device, an n-type cadmium selenide/p-type selenium combination is used to form the heterojunction diode. Both substances are semiconductors which have piezoelectric characteristics – their electric polarization changes as they are subjected to mechanical stress. But, Dr. Moore explained, their polarization changes at different rates and there is a discontinuity in the polarization across the p-n interface. This produces a change in the interface field strengths and p-n depletion regions (from the case of zero strain) that affects the conductivity of the semiconductor diode. As a result, the diode's output voltage varies in direct relationship to the strain imposed upon it and acts as an "electro-mechanical triode" with the sensing and amplifying functions integrated into a single device.

"CONTROLLED COLLAPSE" TECHNIQUE FOR JOINING SEMICONDUCTORS

An improved solder reflow technique for joining semiconductor devices which eliminates rigid contacts was described by an International Business Machines Corporation chemist at the 1968 Hybrid Microelectronics Symposium. The technique prevents solder pad devices from collapsing and shorting-out through contact with surrounding conductor materials.

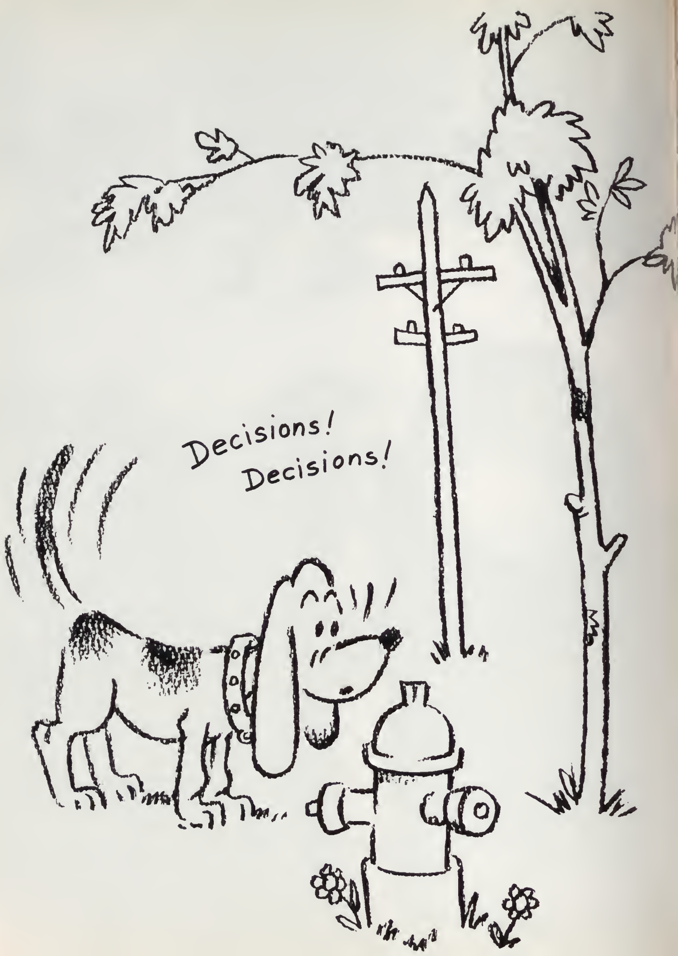
Semiconductor devices have often used rigid contacts because the edges of diced devices might be electrically shorted if they collapsed during joining. The "controlled collapse" technique is based on limiting the module land solderable area with dams or other methods so that the surface tension of the molten pad and land solder support the device thus eliminating the necessity of rigid contacts.

* * * * * * *

Mech Miss

Our December MECH MISS, Paula Cass, is a sophomore transfer student from Port Washington, Long Island. Majoring in math doesn't deter Paula from enjoying her hobbies which include water-skiing and horseback riding. As you may have already guessed, after graduation from G.W. Paula plans to become a computer programmer. When asked about the difference between liberal arts students and engineers:

"I find that engineers are very studious and care much more about their grades than students in other majors. Engineers are also very very forward."


Decisions!
Decisions!

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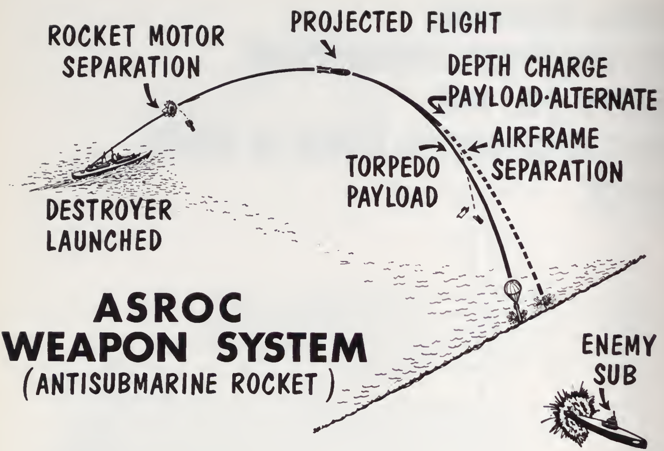

ASROC WEAPON SYSTEM (ANTISUBMARINE ROCKET)

Compiled by Sidney J. Harmon

DURING the late fifties, the emergence of high-performance submarines possessing unlimited endurance, high speed, and great maneuverability, created an urgent need to revise the concepts of anti-submarine warfare. To fill this need to locate, track, and destroy enemy submarines, the United States Navy developed a new anti-submarine warfare concept – the ASROC (anti-submarine rocket) Weapon System. Previously, it had been possible to combat submarines in a close-attack position, but the advanced capabilities of the nuclear-powered undersea craft rendered this attack philosophy impracticable. ASROC, under the control and direction of its high-speed digital computer, permits strikes against these submarines from more extended ranges.

This new weapon system is comprised of sonar detection equipment, an electronic computer, rocket launcher, and missile. It is now the basic ASW (anti-submarine warfare) weapon of destroyers, frigates, and cruisers of the U.S. Fleet.

In operation, the ASROC sonar detection device locates an enemy submarine and bounces short "pings" of sound off its hull to determine its position and depth. This information plus other data, is fed into the computer. The computer then determines the target's future position, accurately aims the rocket launcher, and fires the missile at the precise instant for hitting the target.

The missile is approximately fifteen feet long and carries an explosive payload that may be either an acoustic homing torpedo or a depth charge. In flight, the rocket motor and airframe drop off. If the payload is a depth charge, it sinks to a predetermined depth and explodes, destroying the submarine. If the payload is an acoustic homing torpedo, a

parachute opens as the missile airframe falls away, and slows the descent to the water. After the torpedo hits the water, the parachute detaches and the acoustic homing device guides the torpedo straight to the submarine for the kill.

The Navy selected Honeywell Corporation as Prime Contractor to develop and build the ASROC system. Honeywell, working under the technical direction of the Naval Ordnance Test Station (NOTS) in China Lake and Pasadena, California, produced and installed the first ASROC Weapon Systems in only four years – one year earlier than originally scheduled. The early and successful completion of the program is a classic example of effective cooperation between a military agency and private business to reinforce the nation's defenses.

The Missile Launcher

In January of 1957, the engineering program was started on the MK 16 Mod O Launching Group for the ASROC anti-submarine weapon, with Universal Match Corporation as the subcontractor for the launcher. The Naval Ordnance Plant at York, Pennsylvania, was assigned responsibility for the train and elevation power drives.

Designed to launch ASROC missiles from destroyers, cruisers, and other craft, the Launcher MK 112 Mod O permits stowage of eight missiles in four fully enclosed guides. Each guide has two separate cells which have extendable launching rails. Guide rail extension is effected just prior to missile firing and in turn provides the correct rail length to direct a missile out of its guide cell into the flight path.

Launcher operation is fully automatic. An interlocking system allows elevation of only one guide at a time for aiming and firing. Normally, the launcher is operated with remote control in that the incoming signal from the underwater battery computer brings the mount into synchronization and prepares the missile for firing. The actual firing step of the sequence is a manual operation.

Air motors provide an additional power source in each gear drive to use for maneuvering the mount at greatly reduced speeds in maintaining, servicing, and loading operations.

The Computer System

Development of the first shipboard electronic digital fire-control computer to direct operations in the Navy's anti-submarine weapon system occurred in mid 1960 at the Bureau of Naval Weapons. Librascope Division, General Precision, Inc. developed the computer under the technical direction, again, of NOTS at China Lake and Pasadena, California.

The essential value of the digital computer, in addition to its speed in processing combat information, is the readiness with which it can be modified to accept new data developed from changes in the characteristics of the weapon system.

Basic philosophy of employing a digital computer was to free command and operating personnel for the decisive function of evaluating tactical situations and making final attack decisions. To implement this philosophy, the computer was designed to (1) collect and handle target information; (2) perform the fundamental mathematics of establishing target course, range, and speed; and (3) compute intercept ballistic paths.

The guiding principle in the development of Fire-Control Group MK 111 for the ASROC weapon system was to optimize the performance of both man and machine by delegating to each those operations for which each was best suited. By directing the entire submarine attack based on information developed from the sonar detections system and shipboard instrumentation, the computer provides the solution to the fire-control problem, informs command personnel of the tactical situation, controls the missile, and monitors the weapon performance.

The Missile

The design and development of the ASROC missile with its dual payload capability presented numerous problems. The payload consists of an improved homing torpedo developed by the General Electric Company and a new, compact depth charge, developed by NOTS and Honeywell.

The airframe, which connects the motor and payload, is fashioned of aluminum, and consists of two lengthwise sections, which are hinged to open up like the jaws of an alligator.

In flight, a steel band holding the airframe together is severed by a small explosive charge on a signal from the missile's "brain". The airframe peels off and drops into the sea, leaving the payload to continue its ballistic trajectory.

The missile's control mechanism, which is located inside the airframe, is called the ignition and separation assembly (ISA). On instructions from the shipboard fire-control system, ISA electronically controls range by the ejection of the rocket motor and separation of the airframe.

Handling and Loading

Missiles are usually loaded at dockside, or at anchor, but the system can be replenished at sea. The missile is shipped in a light-weight airtight and watertight container that can be transferred at sea by normal Navy methods. During transfer exercises, the time for transfer of missiles from the supply ship into the launcher was short enough to indicate this method of handling practicable for fleet logistics.

ASROC, the Navy's most potent answer to the submarine threat.

Testing of the ASROC Weapon System

Development of the ASROC weapon system started with an idea and tens of thousands of unanswered questions. The answers were extracted from testing – continual, exhaustive, and painstaking.

The ASROC concept was based on present knowledge at the time the program was initiated. The potential capability of the system was worked out mathematically with probability curves. But it remained for test programs, carried out by the NOTS-Contractor team, to develop ASROC from an idea to hardware.

Early in the program, prototype missiles were test fired statically and from moving platforms at the Naval Ordnance Test Station to obtain aerodynamic research information. Engineers measured, recorded, and computed items and distances for thrust termination, airframe separation, and payload impacts.

Hydroballistic information was obtained from dummy payloads fired into the water from a test stand at Morris

Dam near Azusa, California, and dropped from the wings of airplanes into a hydrophone range of San Clemente Island. Calculations on trajectory, hydrodynamic stability, and depth-time ratios began to contribute to design. Throughout the ASROC development program, more than two hundred test firings were conducted. Along with test firings went a host of other forms of testing. The missile and other components of the system underwent functional, environmental, stress, and shock tests.

The tests at China Lake, Morris Dam, and San Clemente Island ranges and in the laboratories of HOTS and Honeywell were all preparatory to ASROC's final examinations.

The successful Bureau of Naval Weapons evaluation marked the time when ASROC graduated from the hands of its creators to the hands of the men who would reply on it in combat.

To obtain this proof of ASROC's merits, ASROC missiles were fired from the Destroyer-Leader U.S.S. Norfolk under varying weather and sea conditions over a two-month period. Special electronic equipment recorded every facet of ASROC's performance for careful study.

ASROC Launcher loaded and ready to fire. Launcher can cover almost a full circle about ship while ship remains in formation course.

Having passed the first part of its final exam, ASROC was further subjected to exhaustive sea-going trials by the Operational Test and Evaluation Force. The primary purpose of this last trial was to determine the ASROC system's tactical capabilities under fleet operating conditions.

Supporting Equipment of the ASROC System

Shipboard equipment includes a launcher-and-missile simulator and a sonar trainer. These two pieces of equipment electronically simulate actual combat conditions to train operators in the use of sonar equipment, the fire-control computer and attack console.

Shorebased training stations which are located at the Fleet Training Schools at Key West, Florida, and San Diego, California, consist of a complex of equipment that simulates all operable equipment of the ASROC system and provides simulated attack conditions and tactical formations.

Another essential element of missile system development is the careful and detailed study of performance to determine operability of the system and its major components. This requires further instrumentation.

For the ASROC evaluation tests, Honeywell designed an instrumentation control van and an instrumentation recording van that were carried aboard the evaluation ship.

The control van contained a control console with timing devices, panels containing switches for operating instrumentation and monitor lights for indicating the operation of critical weapon system elements.

The instrumentation van contained a wide-band FM tape system, two oscillographs, a photo-data panel, a digital tape system, and a range-time system. Other instrumentation-system equipment includes radar and cameras for missile tracking, sound-powered phone circuits for intraship communications, and a radio link for intership communications.

Conclusion

The successful completion of the ASROC development program has given our Navy's surface fleet a superior weapon for locating and destroying enemy submarines at increased distance and with greater accuracy than was ever before possible.

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THE THEORY OF CONTINUOUS DISTRIBUTIONS OF DISLOCATIONS

By Dr. G. M. Arkilic - Professor and Chairman of the Engineering Mechanics Department of the GWU SEAS

THE PURPOSE of this article is to present to the readers of Mechelecivа brief description of the Engineering Mechanics Department's research activities on Dislocations. It is hoped that this exposition will attract the attention of our students who are considering graduate work in this area of research. This article should be considered neither a complete account of one of our activities nor a survey article on Dislocations. As the subject has been an active research area for the last thirteen years, a brief mention of the historical development must be made. It also will be essential to refer to differential geometry in order to make the presentation meaningful.

The microscopic theory of plasticity of crystalline substance, which considers deformations in atomic scale, utilizes the concept of a particular type of line imperfection of crystal structure known as dislocations. This theory which was originated independently by Taylor (1934), Orowan (1934) and Polanyi (1934) has been developed considerably and has been supported by experiments. A comprehensive account of the development of dislocation theory can be found in the books of Cottrell (1953), Read (1953), Friedel (1958) and van Bueren (1961). However it was not until quite recently that the importance of differential geometry in the quantitative description of that theory of continuous distribution of dislocations was recognized by Kondo (1953), Bilby (1955), Bilby, Bullaugh, Gardner and Smith (1960) and by Kroner (1958). In the following, we shall introduce some of the terminology and basic concepts of this subject without going into the more sophisticated phase of the present stage of development which would be beyond the scope of this article. However, references will be provided for further reading.

Dislocations in Crystals

As early as 1912, x-ray experiments proved that many materials of engineering importance had a crystalline structure. In nature, they are usually found in a polycrystalline state. Here we shall consider a perfect crystalline state of matter and explain its physical properties and, in particular, its plastic behavior. When experiments were made with such crystals, it was found that theoretical critical shear stress is much higher than the measured results by a factor of (10^2 to 10^3). This discrepancy could be explained by assuming that the real crystals do not have a perfect structure and the irregularities, such as edge dislocation and screw dislocations, provide easy glide surfaces which consequently reduce the necessary actual critical shear. The existence of dislocation was supported by x-ray diffraction studies. Consequently one of the most serious objections to the theory of plastic behavior of crystalline substances was eliminated. The edge dislocation may be imagined as being formed by cutting a perfect crystal along an atomic plane and inserting an extra atomic plane along the cut surface. Similarly, the screw dislocation may be formed after having cut a perfect crystal along an atomic plane and moving the left portion upward (with respect to the right portion of the crystal) an amount of one interatomic distance. In both cases the end line of the dislocation surface which is within the crystal is called the dislocation line. In the analytical treatment of the dislocation theory, the Burgers vector defined by the closure failure of a circuit drawn about the dislocation line plays a fundamental role. It should be noted that for an edge dislocation the associated Burgers vector is perpendicular to its dislocation line. For further detail the reader is referred

to Key (1964), Butler (1965), and Abramson, Liebowitz, Crawley, and Juhasz (1966).

Basic Theory

In order to describe a deformed crystalline body B, we shall introduce x^a anholonomic curvilinear (a) coordinates throughout this material space which contains point, line and surface singularities. We shall not require the existence of a metric tensor. Therefore, the space thus introduced is non-riemannian.

In riemannian geometry the fundamental role of a metric tensor is well known; the quantity of primary importance in non-riemannian geometry is the linear connection. We shall assume that our space has single non-symmetric connection $\overset{a}{\Gamma}_{\mu\lambda}$ which is a function of anholonomic (b) coordinates x^a. Due to the non-existence of metric tensor, the length between two infinitely close points cannot be measured in such a space. However, we shall assume that there exists an associated symmetric tensor, say $g_{a\beta}$ (c) throughout B.

The undeformed state of body B is considered in a Euclidean space covered with coordinates $\overline{x}^a$ with its metric tensor $a_{a\beta}$. The most general form of linear connection of the anholonomic system x is given by Schouten (1954) as shown in Eq (1).

$$(1)\quad \overset{k}{\Gamma}_{\mu\lambda} = g^{\rho k}\left[\tfrac{1}{2}\partial\{\lambda g_{\rho\mu}\} - S\{\gamma\rho\mu\} + \Omega\{\lambda\rho\mu\} + \tfrac{1}{2}Q\{\gamma\rho\mu\}\right]$$

where the braced notation is defined in Eq (2)

$$(2)\quad \Psi\{\lambda\rho\mu\} = \Psi_{\lambda\rho\mu} - \Psi_{\rho\mu} + \Psi_{\mu\lambda\rho}$$

In Eq (1) the first term is the Christoffel symbol of the first kind belonging to the associated tensor $g_{a\beta}$; the second term $S_{\lambda\rho\mu}$ is the torsion tensor; the third term $\Omega_{\lambda\rho\mu}$ (d) is called anholonomic object; and the last term is defined as

$$(3)\quad Q_{\mu\lambda x} = -\nabla_\mu g_{\lambda k}$$

where ∇_μ stands for the covariant derivative of the associated symmetric tensor $g_{a\beta}$. If $Q_{\mu\lambda x}$ terms of Eq (1) vanish, then the linear connection $\overset{k}{\Gamma}_{\mu\lambda}$ is said to be (e) metric with respect to the associated tensor $g_{a\beta}$.

In the Fifties it was shown by several investigators that the dislocation density is expressible by the torsion tensor which is defined as

$$(4)\quad S^{a}{}_{\cdot\beta\gamma} = \tfrac{1}{2}\left(\Gamma_a^{\beta\gamma} - \Gamma_a^{\gamma\beta}\right)$$

This definition illustrates the importance of linear connection in the development of the theory. In the following, we shall introduce further physical evidences involving properties of similar geometric terms.

Let us consider the dislocation network in a polycrystal, where the low angle grain boundaries are considered as transition regions formed by the penetration of one monocrystal into another, as shown in Fig (1)

Then the current Burgers vector for the combined circuit ABEFGDA can be written as in Eq (5).

$$(5)\quad \vec{B} = \vec{b}_{(1)} + \vec{b}_{(2)} - \vec{b}_{(3)} = \vec{b}_{(1+2)} - \vec{b}_{(3)}$$

where $b_{(3)}$ represents the transition region. Since the geometric representation of the defect-free (or undeformed)

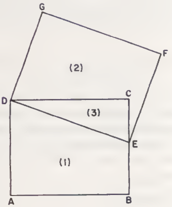

FIGURE 1

state is in a Euclidean space covered with $\overline{x}^a$ (f) coordinates at every point P of B we can interpret this state as the local tangent space to the non-riemannian manifold of the deformed state. This specialization provides the identification of the Cartan Displacement as a Burgers circuit.

Closure failure of a Cartan displacement is given in the form, Schouten (1954)

$$(6)\quad V^a = 2\overset{a}{\Omega}_\beta\, dx^\beta\, dx^\gamma - 2S_{\beta\gamma}\, dx^\beta\, dx^\gamma$$

A comparison of Equations (5 and 6) may lead to the con-

clusion that the Burgers vector of the transition region can be expressed as

$$(7) \qquad b^{\alpha}_{(3)} = 2S^{\alpha}_{\beta\gamma} dx^{\beta} dx^{\gamma} .$$

This shows the association of the torsion tensor $S^{\alpha}_{\beta\gamma}$ with the Burgers vector of the transition region of the polycrystals. Consequently, in the case of a monocrystal torsion tensor $S_{\beta\gamma} \equiv 0$ the anholonomic objects $\Omega^{\alpha}_{\beta\gamma}$ are associated with the true Burgers vectors. For the details of this explanation see Wolko (1967). He also interpreted the anholonomic objects of Eq (1), $\Omega^{\mu}_{\lambda\rho}$, by comparing them with Nye's dislocation density. He showed that the components of $\Omega^{\mu}_{\lambda\rho}$ with repeated indices represent edge dislocations, and, with the repeated lower indices, they represent screw dislocations.

Due to the non-metric character of the space under consideration, we have retained $Q_{\alpha\beta\gamma}$ terms in the linear (g) connection of Eq (1). Kelly (1968) showed that they can be associated with other defects like dislocation dipoles and single dislocations.

Let us now consider the anholonomic curvature tensor, Schouten (1954)

$$(8) \qquad R_{\nu\mu\gamma}^{\;\;\;\;k} = 2\left[\partial_{[\nu}\Gamma^{k}_{\mu]\lambda} + \Gamma^{k}_{[\nu|\rho|}\Gamma^{\rho}_{\mu]\lambda}\right] + 2\Omega^{\rho}_{\nu\mu}\Gamma^{k}_{\rho\lambda}$$

The assumption of distant parallelism or, equivalently, of a zero curvature tensor, will not be valid for a body actually undergoing plastic deformations. It also is not valid near the point of fracture where large-scale voids or vacancies are formed. Since, in a three-dimensional space, the Einstein's matter tensor

$$(9) \qquad \Gamma^{\alpha\beta} = E^{\alpha\gamma\mu} E^{\beta\lambda\mu} R_{\gamma\mu\lambda}$$

may be used in place of the full curvature tensor with no loss of generality, as stated by Seeger (1963), a non-zero curvature tensor means that matter has been inserted into or removed from the crystalline body B, under the plastic deformations. Also it is well known that the vanishing curvature tensor means the existence of distant parallelism in the dislocated media. This approach has been utilized by several authors.

Now we can present some predictions on the behavior of stress-strain curve of a mono-crystalline substance.

In the final deformed state, after having introduced all the singularities, we may define conceptually a strain tensor in the form

$$(10) \qquad e_{\alpha\beta} = \tfrac{1}{2}\left(g_{\alpha\beta} - a_{\alpha\beta}\right)$$

where, $g_{\alpha\beta}$ is the previously defined associated symmetric tensor of non-riemannian space, and $a_{\alpha\beta}$ is the metric of tangent space. The covariant differentiation of strain tensor is

$$(11) \qquad \nabla_{\gamma} e_{\alpha\beta} = \tfrac{1}{2} \nabla_{\gamma} g_{\alpha\beta}$$

where, from Schouten (1954),

$$(12) \qquad \nabla_{\gamma} g_{\alpha\beta} = \partial_{\gamma} g_{\alpha\beta} - \Gamma^{\rho}_{\gamma\alpha} g_{\rho\beta} \cdot \Gamma^{\rho}_{\gamma\beta} g_{\alpha\rho}$$

and since the covariant differentiation of $g_{\alpha\beta}$ is defined

$$(13) \qquad \nabla_{\gamma} g_{\alpha\beta} = -Q_{\gamma\alpha\beta}$$

consequently we obtain the following relation:

$$(14) \qquad \partial_{\gamma} g_{\alpha\beta} = Q_{\gamma\alpha\beta} + \Gamma^{\rho}_{\gamma\alpha} g_{\rho\beta} + \Gamma^{\rho}_{\gamma\beta} g_{\alpha\beta}$$

Using Schouten's (1954) notation this simplifies to

$$(15) \qquad \partial_{\gamma} g_{\alpha\beta} = 2\Gamma_{\gamma(\alpha\beta)} - Q_{\gamma\alpha\beta}$$

The strain increment $de_{\alpha\beta}$ now can be written as

$$(16) \qquad de_{\alpha\beta} = \left[\Gamma_{\gamma(\alpha\beta)} - \tfrac{1}{2} Q_{\gamma\alpha\beta}\right] dx^{\gamma} .$$

At the early stages of deformation, since no grain boundaries are present and dislocation in the crystal may only occur as dipoles, we may look at this stage as compatible deformations. That is, the linear connection of this stage is identical with the Christoffel symbols of $g_{\alpha\beta}$ of a riemannian space, namely,

$$(17) \qquad \Gamma^{\gamma}_{\alpha\beta} \equiv \left\{ {\gamma \atop \alpha\beta} \right\} \therefore \Gamma^{\gamma}_{[\alpha\beta]} \equiv 0$$

This is expected since there are no closure failures associated with Burgers circuit in the crystal.

As long as non-metric quantities are not introduced by confining the deformations to a compatible field, the strain increment will reduce to the following form

$$(18) \qquad de_{\alpha\beta} = \left[\alpha\beta;\gamma\right] dx^{\gamma}$$

which is the kind of deformation considered in the theory of elasticity. This is due to the fact that the distribution of dislocations (though few) are not changed. Therefore all the other terms will vanish in Eq (16). We may refer this state to the linear region of stress-strain diagram as indicated in Fig (2).

When the resolved shear stress τ reaches a critical value τ_c corresponding to a strain field of the order 10^{-4}, Frank-

Read sources begin generating new dislocations, and dislocation pairs already present begin to move. With the previously introduced interpretations of geometric objects, the terms like $\Omega_{\beta\alpha}^{\gamma}$ begin to appear. Consequently

$$(19)\quad \Gamma^{\gamma}_{[\beta\alpha]} \neq 0$$

We associate this stage with the easy glide as shown in Fig (2). As the deformations progress, dislocation with

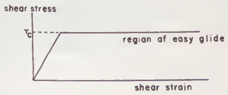

FIGURE 2

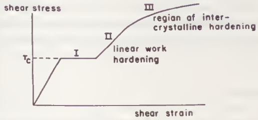

FIGURE 3

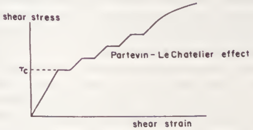

FIGURE 4

Burgers vectors of different magnitudes combine to form nodes; this eventually results in the formation of the so-called Frank network. We interpret this as the appearance of $S_{\gamma\beta\alpha}$ (torsion tensor) in Eq (19). Therefore, it takes the form

$$(20)\quad \Gamma^{\gamma}_{[\beta\alpha]} = S_{\beta\alpha}^{\cdot\cdot\gamma} - \Omega_{\beta\alpha}^{\gamma}.$$

If the network develops to the extent that

$$(21)\quad S_{\beta\alpha}^{\cdot\cdot\gamma} \cong \Omega_{\beta\alpha}^{\gamma}$$

then a behavior similar to Eq (17) may result which is given in Fig (3) as the region of linear work hardening.

It should be remarked here that in the case of a polycrystal, slip may start in different grains at different times during deformation and may terminate when Eq (21) is satisfied. This may happen several times, producing easy glide and linear hardening regions, as shown in Fig (4), which is known in the literature as the Portevin-le Chatelier effect.

At large plastic strains, slip occurs freely in a single crystal of a face centered cubic metal. Again, hardening is almost entirely intercrystalline in the third stage of the plastic deformation, resulting in the growth of the $Q_{\gamma\beta\alpha}$ term. This stage is also shown in Fig (3) as the region of intercrystalline hardening. In this stage, slip bands and pronounced necking of the specimen may be observed.

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RECRUITERS FLOCK TO NEGRO COLLEGES

By Robert Skole

FIVE YEARS AGO, recruiters seeking the engineering graduates of predominantly Negro universities were about as numerous as black faces at an IEEE meeting. Today, the status quo still prevails at technical get-togethers, but the campuses were overrun by recruiters this spring.

The rush to hire black engineering graduates is, in most cases, prompted by Federal equal-employment regulations covering Government contracting.

But some companies began to hire blacks years ago and gave them real opportunities for advancement. Many others waited and made only token efforts. And even today, some firms only go through the motions of recruiting black engineers or take on a few as showpieces.

Because so many recruiters are besieging the Negro universities, competing hard for the engineering graduates, the placement directors at these institutions are saying: "We'll be keeping out those companies that haven't been sincere and working harder with those that have given our graduates the best opportunities."

Bench Marks

The situation is still fluid, not only because of the dynamics of the civil-rights movement but also as a result of ambivalent attitudes on the part of both blacks and whites. However, certain patterns are clearly discernible:

–Smaller companies without extensive recruiting programs face tough going even when they sincerely want Negro engineers.

–Although Negro universities are turning out relatively few electrical engineers – about 100 from the dozen schools offering such degrees – there will be a big increase in future years, making these schools far more attractive from a quantity standpoint. Meanwhile, moves are being made to upgrade curriculum quality.

–Some recruiters and personnel managers are so far out of touch with Negro students that they will find it tough to catch up with efforts made by more understanding officials.

Roundup

Electronics firms are increasing their efforts to recruit at Negro universities at a rate far greater than most other industries. "I wish we had five times as many engineers graduating this year," says W.I. Morris, placement director of A&T College, Greensboro, N.C. "In the last six years we've certainly had a 100% improvement in the number of recruiters coming here."

A&T had a dozen EE grads in a senior class of 425 this year; overall, only 60 were science majors. "For so many years, opportunities in engineering were not open to us," says Morris. "But prospects are brighter today. Each of our engineering graduates had three to six job offers."

The dramatic growth in the number of recruiters seeking black graduates is apparent in data from Southern University, Baton Rouge, La. In 1960, 15 recruiters went to the school; 12 were after teachers and three were from Federal agencies. This year, there were 556 recruiters on campus only 55 of whom were seeking teachers.

"About 50% of the recruiters were looking for engineers, and a large part of these were after EE's," says James McKay, placement director for Southern U. The school graduated 24 EE's this year, and each averaged eight job offers.

Bigger Rosters

This is now more or less typical of Negro universities. Also typical is an increase in engineering enrollment. In 1967, Southern's engineering department – which graduated 40 this year – had a total enrollment of 450; the 1968 figure was 570. Thus, in a few years, the number of graduates will double.

Because of the intense competition for the relatively few graduates, many companies don't feel the effort is worth it. And some companies will say – privately, of course – that they don't think the scholastic standards at Negro institutions are high enough for them to go to the trouble of recruiting there.

In general, the approach to recruiting at Negro universities is the same as at white schools. However, few firms have tried to tailor their programs. For example, when they were new to this whole thing, some companies thought it would be a good idea to send Negro recruiters to Negro schools. This didn't work well, especially when the recruiter was obviously not professional. Students resented the companies' patronizing attitudes.

However, some firms today send an integrated team to Negro universities – a white professional personnel man accompanied by a Negro engineer or scientist. The white recruiter will talk to the prospect about the job and the company, and then leave the Negro alone with the student "to tell it like it is." Most Negro college placement directors have serious doubts about the effectiveness of this approach.

"One of the biggest problems facing companies that want to hire our students," says Southern U's McKay, "is the quality of the recruiter – they often can't identify with the students."

Placement directors agree that students can easily identify an "insincere" recruiter, and they're getting ready to lower the boom. "It's going to be very necessary to screen the companies and recruiters in the future," says McKay. "We know the recruiters who come just for show."

Shortcomings

A major problem facing most Negro universities is the lack of facilities for recruiters and adequate job-counseling and placement services. And even though it is understandable that no Negro college administration a few years ago would have believed there would be an urgent need for such facilities, there are still recruiters who can't figure it out. A personnel director with a large West Coast aerospace firm, who insists on remaining anonymous, grumbles: "Interviewing rooms are about as big as my desk and the furniture must have been left over from the Civil War."

Because of a lack of facilities, most Negro schools have good reason to screen companies and concentrate only on those with a history of "sincerity". Officials say Negro universities will no longer be "used" by companies that simply go through the motions. "I'm convinced some companies are not sincere," says Walter G. Hawkins, placement director at Howard University, Washington, D.C. "This is particularly true of insurance and banking. But there are some in engineering, and they can least afford the luxury of prejudice."

Paeans

IBM receives high praise on Negro campuses. Hawkins says that although he and his staff try to be impartial, the track record of IBM and some other companies is so good that they naturally do all they can to help these firms. IBM, for example, interviewed more Howard students than any other company this year: 60 graduating seniors. It made 15 job offers, and eight students accepted. On the other hand, some lesser-known companies that don't have a reputation on Negro college campuses have trouble even getting students to interview.

For example, Ampex got only two applicants from Howard this year, the first time it recruited at the school. "We were terribly disappointed," says Arthur O. Stoefen,

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Robert Skole, Washington bureau manager for "Electronics Magazine," has been reporting business and technical news for McGraw-Hill publications for six years. Before joining "Electronics" in Washington last year, he was correspondent in Sweden for McGraw-Hill World News. While in Sweden, he also broadcast for the International Service of the Swedish Broadcasting Service and wrote for Swedish publications. A graduate of the University of Missouri School of Journalism, Skole worked for weeklies and dailies in Boston and Florida, and also worked on papers in the Bahamas and in Tokyo.

the company's recruiting chief. Figuring the averages, however, Ampex did very well. Howard had 100 engineering graduates this year, 30 of them EE's. But 400 companies were after engineering talent at the schoool.

Some companies know very little about desires of Negro graduates. While most engineering graduates want to work in the Northeast or on the West Coast, where housing is generally less of a problem, Stoefen, for one, says he feels that the students at Howard didn't want to move to the coast. And Richard G. Hennemuth, vice president for industrial relations at the Raytheon Co., Lexington, Mass., says: "We have considered recruiting at Tuskegee Institute in Alabama, but our experience has been that neither blacks nor whites like to come this far north. Generally, we find about 50% of our new engineers in the New England area, though we recruit throughout the country."

Pro and Con

Companies are taking different approaches in working with Negro universities and students. Some, like Hewlett-Packard, donate laboratory equipment to colleges. Others with years of experience working with Negro educators and placement directors – for example, IBM – arrange luncheon meetings to get faculties to pass the word that the company is seriously looking for a broad range of graduates.

But some companies appear to have taken a hard-nosed attitude and researched themselves right out of this market. TRW Systems, Redondo Beach, Calif., formed a team of scientists, engineers, and personnel specialists to visit Negro universities to get a "feel" for the schools. "We intended to add them to our campus recruiting schedule," explains James Lacy of the placement staff. "But we rejected the idea because their graduates were not, in our view, equipped to handle the technical tasks required of them here." Many companies say the same thing, but don't want to be identified, even though most Negro administrators agree that their schools are indeed deficient in curriculum and equipment.

Disadvantaged

The Negro graduate of a predominantly white school is as capable as a white graduate, stresses Rober Thomson, director of manpower planning at the Bendix Corp. "But at the predominantly Negro school," he says, "the student is at more of a disadvantage. Here the engineering program may have been in existence only five years. Where the engineering curriculum is very new it takes longer to get top-quality grads. In the past three years, however, we have seen a narrowing of the gap."

Some companies have set up programs to compensate for educational shortcomings of graduates of Negro schools. The Western Development Laboratories division of the Philco-Ford Corp., for example, will sometimes bring a graduate of a Negro university who doesn't measure up to the average grad and give him supplemental job training and support to continue his education.

Other companies, for example the one whose recruiter complained about the Civil War furniture, flatly write off the scholastic competence of most Negro universities. "The graduates can read and write and that's about all," says the company's top employment officer. "Spending money to recruit Negro engineering graduates from predominantly Negro colleges in the south is like throwing money down a rat hole."

Old Story

This kind of attitude is familiar to Negro educators and students. "I have a feeling that company representatives are often laboring under a stereotype," says Fred Scott, placement director of Hampton Institute, Hampton, Va.

Most educators, administrators, and students realize that many companies will hire a few blacks for show. "But I don't think the electronics industry is as guilty in this regard as others," says Scott.

Uneasy Dialogue

One of the major problems remains communications between the recruiters and prospects. Most recruiters say that students at Negro universities aren't as well prepared for interviews as their white counterparts. Officials and faculty members at Negro schools respond that this comes of companies' precipitate rush to hire blacks; the move is so new that the schools haven't had a chance to organize for it.

Phillip M. Oliver, industrial relations director for Philco-Ford's Western Development Lab, says: "At any college, where we find a black engineer, we hire him. I regularly visit a half-dozen Negro colleges. Their real problem is getting men to appear for an interview and to condition them for competition in the white world. They want this competition – but they aren't trained to accept it.

"They are almost like foreigners in their own country in that respect. Take, say, an engineer from Indonesia; he might want very much to win a job and get ahead, but he wouldn't know exactly how to go about it. Some of the Negro graduates are in the same position, like fish out of water."

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APPLICATION OF ENGINEERING TO CARDIOLOGY

THE USE OF AUTO- AND CROSS-CORRELATION ANALYSIS FOR THE DETECTION OF CARDIAC ARRHYTHMIAS

By Jorge I. Aunon

THE PURPOSE of this study was to apply auto- and cross-correlations to electrocardiograms as a monitor of the cardiac cycle. It is conceivable that dangerous types of irregularities (arrhythmias) could be detected almost instantly and the proper personnel warned.

The cardiac cycle as measured by the electrocardiogram, which is a graphic record of the electrical activity of the heart, is normally composed of four waves (Fig. 1), P, Q, R, S, and T. In the normal heart, such a cycle will repeat itself anywhere from 60 to 100 times a minute. A cardiac arrhythmia denotes any irregularity of the heart beat.

The autocorrelation described the dependence of time sampled values of data at one time with the values at another time. Consider a sample time history x(t). An estimate for the autocorrelation between the values of x(t) at times t and $t+\tau$ may be obtained by taking the product at these relative values and averaging over the time of observation, T.

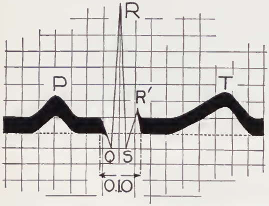

FIG. 1—THE QRS COMPLEX AND THE UPPER LIMITS OF NORMAL DURATION FOR THE AVG. NORMAL CARDIAC CYCLE.

In equation form,

$$R_{xx}(\tau) = 1/T \int_0^T X(t)X(t+\tau)\,dt \qquad (1)$$

In stochastic stationary processes, the limit $T \to \infty$ is used to define R_{xx}. In the present work, however, the function is useful for short times, i.e., several heart beats. We sacrifice the mathematical definition for physical applicability. We assume $x(t) = 0$ for $t > T$.

The quantity $R_{xx}(\tau)$ is always a real-valued even function with a maximum at $\tau = 0$. At other values of τ, the function may be either positive or negative.

In equation form,

$$R_{xx}(-\tau) = R_{xx}(\tau)$$

$$R_{xx}(0)\ |R_{xx}(\tau)|\ \text{for all } \tau$$

The autocorrelation may be viewed as sliding one time series over a duplicate of itself and summing the products at corresponding points.

The cross-correlation function is similar to the auto-correlation function but involves two different functions.

In equation form, the cross-correlation function may be computed by:

$$R_{xy} = 1/T \int_0^T X(t)Y(t+\tau)\,dt \qquad (2)$$

The function $R_{xy}(\tau)$ is always real-valued and may be either positive or negative. Furthermore, $R_{xy}(\tau)$ does not necessarily have a maximum at $\tau = 0$, nor is $R_{xy}(\tau)$ even valued as for autocorrelation functions.

For the purpose of our study, a computer algorithm called the Fast Fourier Transform (FFT) (McCowan, 1967;

Cooley and Tukey, 1965) was used. The FFT is a computer algorithm that computes the discrete Fourier transform much faster than other algorithms. The correlation functions as defined by (1) and (2) are usually computer digitally by forming the lagged product

$$1/N \left[\Sigma x_1(t-\tau)x_1(\tau)\right] \qquad (3)$$

where ranges from 0 to N-1

or

$$1/N \left[\Sigma x_1(t-\tau)x_2(\tau)\right] \qquad (4)$$

where ranges from 0 to N-1

This calculation consumes considerable computer time with conventional techniques. Using the FFT, one can reduce computing time as follows: First, $X_1(t)$ and $X_2(t)$ are Fourier-transformed, yielding $S_1(f)$ and $S_2(f)$. $S_1(f)$ and $S_2(f)$ may be defined by:

$$S(n\Delta f) = \sum_{k=0}^{n-1} x(k\Delta t)\exp(-j2\Pi n(\Delta t\Delta f)k) \qquad (5)$$

$$n = 0, \pm 1, \pm 2, \ldots, \pm N/2$$

Terms $S_1(f)$ and $S_2(f)$ are then multiplied and the resultant is inverse-Fourier-transformed by use of the FFT.

Note that

$$R_{xy}(t) = \sum_{\tau=0}^{N-1} X_1(t-\tau)X_2(\tau) = X_1(t) * X_2(t) \qquad (6)$$

where * signifies convolution

and the Fourier transform of $R_{xy}(t)$ is given by

$$S_3(f) = S_1(f) \cdot S_2(f) \qquad (7)$$

We are using the property that the transform of the convolution of two functions is equal to the product of the transforms of the individual functions.

One possible limitation to this technique is that the number of sample points has to be chosen according to the relation $N=2^n$, where n is an integer. If our number of sample points falls between two values ofof 2^n, we can add zeros at the end of our data with little effect on the resulting function.

It has been estimated that for N = 4096 points, the FFT technique used for calculating auto- and cross-correlation is 80 times faster than previous methods.

Two electrocardiograms were used in this study:

Case I, Normal Sinus Rhythm;

This is a normal type of electrocardiogram with heart rate between 60 and 100 beats/minute and P wave always present.

Case II, Atrial Fibrillation;

Without going into much detail, P-waves (Fig. 1) are absent in this type of arrhythmia.

The traces were sampled at 500 per second and were passed through a 24 db/octave analog filter set at 0.1 and 100 Hz. A 60 cycle noise problem was present in the signals probably due to differences between the recording and playback equipment. A numerical phaseless notch filter was designed to reject the 60 cycle noise and leave the original signal essentially intact. Figure (2) shows this effect of the filter acting on the normal trace.

The mean of the three signals was removed and their auto-correlation computed (Fig.'s 3 and 4). Some interesting features of the signal appear in the auto-correlation (Fig. 3). This is just one side of the auto-correlation as the other is perfectly symmetrical with the one shown here ($R_{xx}(-\tau) = R_{xx}(\tau)$).

Peak A is the mean square value of x(t). Peak B, the small negative peak, is obtained when peaks 1 and 2 are superimposed; later the auto-correlation becomes less nega-

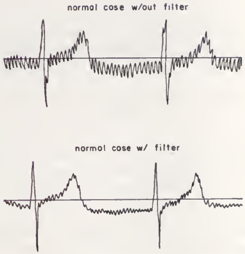

FIG. 2 - EFFECT OF NOTCH (60cps) FILTER ON TRACE

tive and we obtain peak B_1. Peak C is obtained when peaks 1 and 3 are superimposed, etc... The value in time, at which peak E occurs, (superposition of peaks 1 and 4) represents the best statistical estimate of the heart rate of the auto-correlated heart beats. Thus, information about the heart rate is not lost through this technique.

Changes in the shape or rate of the electrocardiogram are contained between T_0 and T_1 where T_1 is the value in seconds that corresponds to the largest lag value between two consecutive R (Fig. 1) waves, so that in future studies where this auto-correlation technique is used, lag values

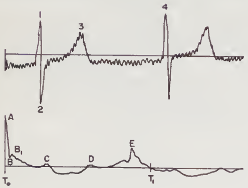

FIG. 3 – AUTOCORRELATION OF NORMAL TRACE

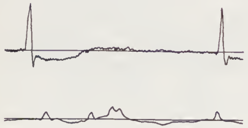

FIG. 4 – AUTOCORRELATION OF ATRIAL FIBRILLATION

extending only to T_1 need be plotted and will contain the necessary information.

As expected, the auto-correlation functions of the three traces showed considerable differences.

Next, we used cross-correlation. A digital computer program was written that would locate the top of the QRS complex of a particular beat (maximum positive value) and then select a fixed number of points on either side of the first signal to be cross-correlated. A similar procedure was followed for the second signal, the signals were lined up using the top of the QRS complex as a reference, and then cross-correlation was performed.

Figure 5 shows the cross-correlation at Normal Complex 1 with Normal Complex 2. Figure 6 is the cross-correlation of Normal Complex 1 with Atrial Fibrillation 1. Figure 7 shows the cross-correlation of Atrial Fibrillation 1 with Atrial Fibrillation 2. It may be noticed that the cross-correlation function is two-sided, that is $R_{xy}(-\tau) \neq R_{xy}(\tau)$.

So long as normal complexes are being cross-correlated, the cross-correlation function is well behaved, i.e., is an almost even function if the complexes are similar. The biggest peak is the one obtained when the two complexes line up, that is the QRS, and the rest of the pattern fall on top of one another.

When a normal complex is cross-correlated with one characteristic of atrial fibrillation, a change occurs in the

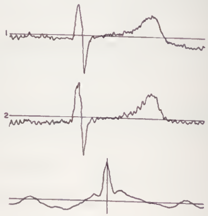

FIG. 5 – NORMAL 1 WITH NORMAL 2

cross-correlation (Figures 6,8). The pattern becomes badly behaved, i.e., contains a large odd part as dissimilarity increases, and the relative value of the maximum decreases greatly in magnitude. (Due to scaling of the figures, the absolute change in magnitude is not obvious.)

The need for a real-time continuous monitor of cardiac arrhythmia is evident. Sloman et al (1968) conducted a study in the Royal Melbourne Hospital, Australia where a new coronary care unit was established in March, 1963. Out of 300 patients investigated in detail, 40 per cent had at least one incident of a serious arrhythmia during their period of observation.

At present, no successful generalized monitor of cardiac arrhythmias is available. Only rate meters and some

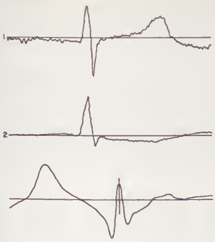

FIG. 6 – NORMAL I WITH ATR. FIB. I

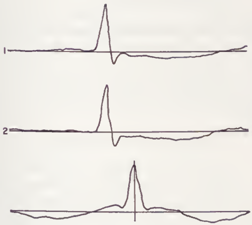

FIG. 7 – ATR. FIB. I WITH ATR. FIB. 2

sophisticated detectors of a particular type of arrhythmias are available. It is therefore conceivable that an instrument incorporating the techniques outlined in this paper could improve detection of arrhythmias.

I would like to point out that this paper merely serves to state a principle. Certainly, two EKG's are by no means enough evidence to prove the method. The signals were poorly recorded and no record exists (to my knowledge) of

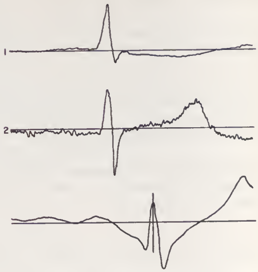

FIG. 8 – ATR. FIB. I WITH NORMAL I

the leads used. However, I believe that the point is made: two cardiac signals essentially different were auto- and cross-correlated yielding significantly different auto- and cross-correlation functions.

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CAMPUS NEWS—FROM PAGE 9

counselors, and principals, as well as the junior college faculties.

Mr. Brown will also take over the SEAS admissions and will endeavor to update all procedures, with a view toward computerizing the entire admissions system. It is anticipated that the computerized system will make all admission, registration, and grade statistics immediately available for all planning purposes.

Mr. Brown's formal education:

1966—Department of Defense Computer Institute Intermediate Executive Course—An Introduction to the Capabilities and Operation of Automatic Dad Computers.

1960—National War College—National Security Policy and International Affairs.

1950—Naval War College—Strategy and Tactics and International Relations.

1938—Bachelor of Science in Engineering. United States Naval Academy.

Mr. Brown's professional experience includes:

Personnel—Directly assisted in the administration and coordination of the officer distribution, enlisted personnel, recruiting, officer promotion and retirement, and personnel transportation divisions in the Bureau of Naval Personnel (20 months); was responsible for the administration and distribution of all enlisted personnel within the Submarine Force Pacific Fleet (18 months); Personnel Officer of the Submarine Base, New London, Connecticut (10 months).

Engineer and Repair—Initiated and developed policy for the maintenance, material readiness, and disposal of submarines, submarine tenders, and deep sea rescue vessels in the Fleet Maintenance Division of the Office of the Chief of Naval Operations (36 months).

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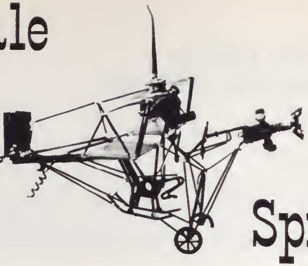
Tale



Spin

The year is 2001, and the Martians have taken over the Earth. One of their favorite foods is human brains. So Zip, a hungry Martian, went down to his neighborhood grocery store to buy a pound of brains.

Zip: "What ya got for brains today?"

Grocer: "We got some Engineers' brains here for $.50 a pound, some Pre-Med brains for $1.00 a pound, and some Liberal Arts' brains for $4.00 a pound."

Zip: "Why so much for Liberal Arts' brains?"

Grocer: "Do you know how many Liberal Arts students we have to kill to get a pound of brains?"

* * *

When he arrived at Hell, the newcomer was given a choice of three doors in which to enter. He opened the first door and everyone inside was burning. He decided that wasn't for him. He opened the second door and found everyone being whipped. That wasn't for him either. He opened the last door. Everyone was up to his neck in manure, drinking coffee next to a bar. Finding nothing objectionable about that, he waded up to bar and asked for a cup of coffee. After about three minutes a voice sounded over the public address system. "Alright, coffee break over. Everyone back on his head."

* * *

Did you hear about the girl who was so ugly the Peeping Toms would reach in and pull down her shades?

* * *

Prof.: "You missed my class yesterday, didn't you?"

M.E.: "No sir, not a bit."

Patient (shortly after returning from the operating room): "Why are all the blinds drawn, Doctor?"

Doctor: "There's a big fire across the street, and I didn't want you to wake up and think the operation was a failure."

* * *

Farmer: "Doctor come right over, my cow has gone cross-eyed."

Vet.: "O.K. I'll be right over."

Vet.: (an hour later) "Hand me that rubber hose in my bag. I'm going to stick one end up the cow's rectum and blow on the other end. You tell me when the eyes straighten out."

Farmer: "O.K. they're straight."

About a month later the same thing happens to the same cow. So instead of calling the Vet. the farmer decides to do it himself. He gets an old siphoning hose and a farmhand to help him out.

Farmer: "All right tell me when her eyes straighten out."

Farmhand: "Nothing seems to be happening."

Farmer: "You come back here and blow on the hose and I'll watch her eyes."

The farmhand goes to the back of the cow, pulls out the hose and puts the other end up the cow's rectum, and begins to blow.

Farmer: "Why did you do that?"

Farmhand: "Did you think I was going to put my mouth on the same hose you had your mouth on."

* * *

A snowflake in an avalanche never feels responsible.

Bob Nerad seeks recognition

But not just for himself.

Bob was Chairman of a special Jaycee project to select the "Outstanding Young Educator" in Schenectady, New York.

He began by rediscovering firsthand some of the vibrant situations that confront young teachers. With that background he was ready to coordinate the nominating and judging.

Planning and coordinating come naturally to Bob. As a Production Control Specialist with General Electric's Medium AC Motor and Generator Department, he keeps production lines running smoothly. Coordinating machinery, raw materials and labor is crucial to any efficiently run business.

With a mechanical engineering degree from Cornell, in 1962, and an MBA in personnel administration from George Washington, in 1963, Bob sought to plunge directly into meaningful work. He'd had enough theory and simulations to last him for awhile.

At General Electric he found people that agreed with his thinking, and what's more, GE offered him immediate responsibility via the Manufacturing Management Program.

Like Bob Nerad, you can get a fast start at General Electric, in R&D, design, production or technical marketing. Talk to our man when he visits your campus. Or write for career information to: General Electric Company, Room 801B, 570 Lexington Avenue, New York, N. Y. 10022

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